DOCUMENT RESUME

ED 225 818 SE 040 060

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TITLE Sludge Lagoons. Sludge Treatment and Disposal Course #166. Instructor's Guide [and] Student Workbook.
INSTITUTION Linn-Benton Community Coll., Albany, Oreg.
SPONS AGENCY Office of Water Program Operations (EPA), Cincinnati, Ohio. National Training and Operational Technology Center.
PUB DATE Aug 80
GRANT EPA-900953010
NOTE 43p.; For related documents, see ED 224 718-720 and SE 040 061-062.
AVAILABLE FROM Linn-Benton Community College, 6500 SW Pacific Blvd., Albany, OR 97321 ($1. student workbook, $2. instructor's guide, cost per entire set of slide-tape, 1 student workbook and 1 instructor's guide is $75. per unit); EPA/Instructional Resources Center, 1200 Chambers Rd., 3rd Floor, Columbus, OH 43212, prices from EPA are available upon request.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051) -- Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Instructional Materials; Laboratory Procedures; Post Secondary Education; Safety; *Sludge; Teaching Guides; *Training Methods; *Waste Water; *Water Treatment
IDENTIFIERS Sludge Lagoons

ABSTRACT

This lesson describes three different types of sludge lagoons: (1) drying lagoons; (2) facultative lagoons; and (3) anaerobic lagoons. Normal operating sequence and equipment are also described. The lesson is designed to be used in sequence with the complete Sludge Treatment and Disposal Course #166 or as an independent lesson. The instructor's manual contains a description of the lesson, estimated presentation time, instructional materials list, suggested sequence of presentation, reading lists, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers). The student workbook contains plant flow diagrams, objectives, glossary, text material, references, and workshet. Tables listing advantages/disadvantages of using sludge drying lagoons and advantages/limitations of using facultative sludge lagoons for long-term storage are included. Safety measures are briefly considered. (Author/JN)

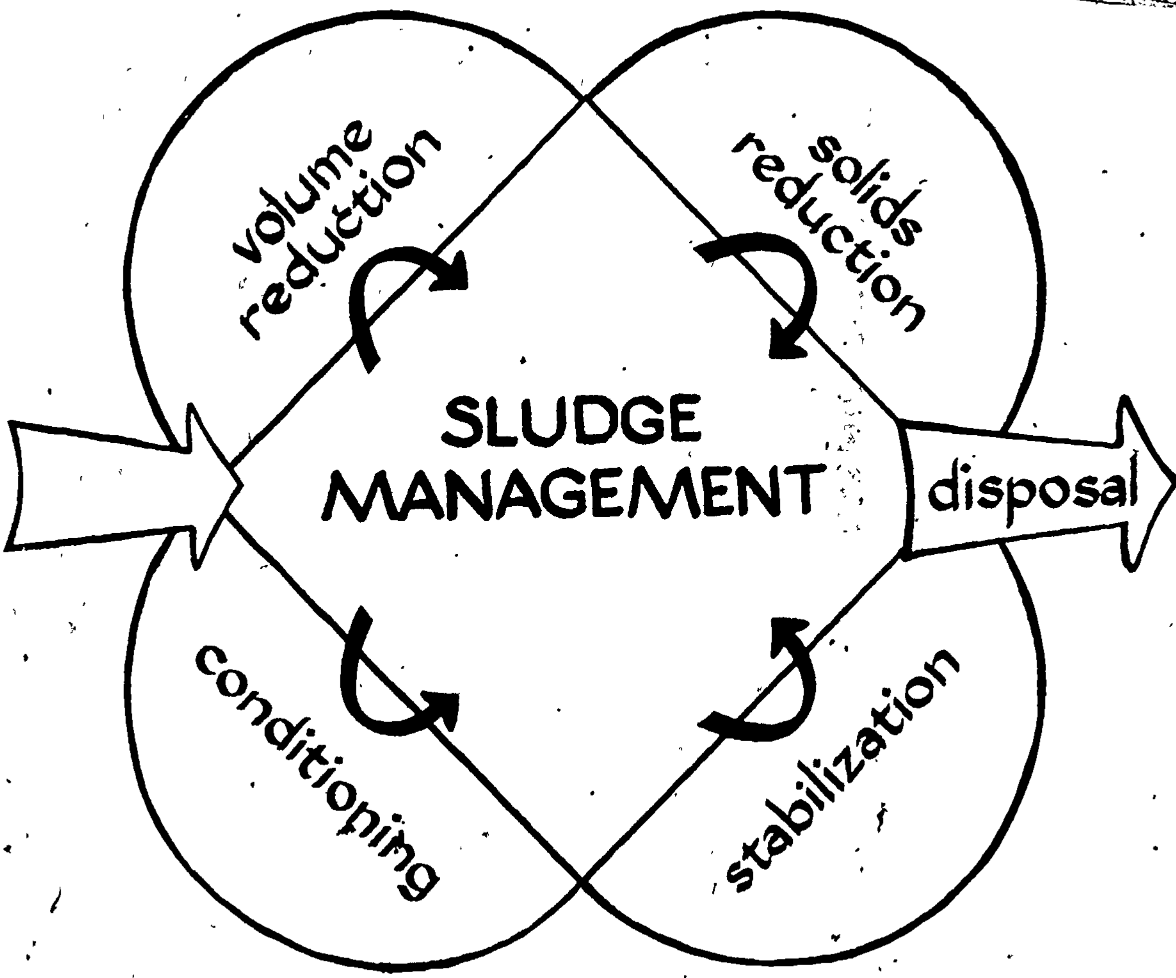
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

SLUDGE LAGOONS



INSTRUCTOR'S GUIDE

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

SLUDGE LAGOONS

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Developed Under:
EPA Grant #900953010
August, 1980

SLUDGE LAGOONS

CONTENTS

SLUDGE LAGOONS

LESSON DESCRIPTION

This lesson is designed to be used in sequence with the complete Sludge Treatment and Disposal Course #166. It can be used independently as a complete lesson.

This lesson describes the three different types of sludge lagoons; drying, facultative and anaerobic lagoons. Discussion is made of the normal operating sequence and the equipment involved.

ESTIMATED TIME

Student preview	5-10 minutes
Presentation	17 minutes
Discussion	10 minutes
Worksheet	10-15 minutes

INSTRUCTIONAL AIDS

1. Student text "Sludge Lagoons"
2. Slide set "Sludge Lagoons"
3. Slide projector
4. Screen
5. Design drawings of local lagoon systems.

SUGGESTED SEQUENCE OF PRESENTATION

1. Assign reading - emphasis on glossary and objectives.
2. Lecture using slide set.
3. Open discussion.
4. Assign worksheet.
5. Correct worksheet.

REQUIRED READING

Student text "Sludge Lagoons"

REFERENCE READING

Process Design Manual - Sludge Treatment and Disposal, pages 9-14 through 9-17, 15-22 through 15-50

SLUDGE LAGOONS

OBJECTIVES

Upon completion of this lesson the student will be able to do the following:

1. Explain how lagoon, as a treatment process, fits into the overall wastewater treatment scheme.
2. Explain why a sludge drying lagoon resembles sludge drying beds.
3. Describe the equipment which is common to all sludge lagoon variations.
4. List the six operating procedures common to all types of lagoon systems.
5. Explain how the following design criteria affect sludge lagoon operation:
   a) Climate
   b) Subsoil permability
   c) Sludge characteristics
   d) Depth and area
6. Recall that lagoon storage is not suitable for unstabilized, dewatered, or partially dired sludge because of the problems with septicity.
7. Describe sludge drying lagoons.
8. Recall the sludge loading rate if the sludge drying lagoon is 2.2 - 2.4 lbs/yr/ft^3 of lagoon capacity.
9. Describe facultative sludge lagoons.
10. Recall that the sludge loading rate of the facultative lagoon is 20 lbs VS/1,000 ft^2/day.
11. Describe anaerobic sludge lagoons.
12. Explain the mechanisms of O_2 supply in a facultative lagoon.
13. Explain why receiving undigested feed sludge is the major emergency encountered during lagoon operation.
14. Recall that lagoons are used for dewatering, further decomposition, and storage of wastewater sludges.
15. Describe the general maintenance considerations of sludge lagoon systems.
16. Describe the causes of odor problems and what can be done to solve them.
17. Explain the effects of poor supernatant quality on the treatment plant and what can be done to improve on supernatant quality.

LECTURE OUTLINE

I. INTRODUCTION

A. Method of Sludge Dewatering

1. Similar to drying beds

B. Drying and dewatering accomplished by:

1. Decanting supernatant
2. Evaporation
3. Drainage
4. Transportation

II. BASIC CONCEPT

A. Different operational variations have common design, equipment, and operational requirements.

B. Design and equipment

1. Rectangular shape, retaining walls
   a. Drying lagoons, 2-4 foot high
   b. Anaerobic lagoons, 35 foot depth
2. Equipment
   a. Sludge feed line
   b. Metering pumps
   c. Supernatant decant lines
   d. Sludge removal equipment

C. Operating procedures

1. Pump liquid feed sludge
   a. Normally stabilized
2. Decant supernatant
   a. Continuously
   b. Intermittently
3. Fill to desired depth and allow to dewater
4. Remove dewatered sludge
5. Resting stage
   a. 3 to 6 months
6. Repeat the cycle

D. Design Criteria

1. Climate
2. Subsoil permeability
3. Sludge characteristics
   a. Anaerobically digested
4. Depth and area
   a. Drying lagoons - 2 2-2.4 lbs/yr/ft^3
   b. Facultative lagoons - 20 lbs VS/1000 ft^2

III. LAGOON TYPES

A. Sludge Drying Lagoon
1. Resemble drying beds
2. Sludge exposed to air
3. 2.2-2.4 lbs/yr/ft^3
4. 24-48 inch depth

B. Facultative Sludge Lagoons
1. Aerobic surface area
   a. Surface mixers (brush)
   b. O_2 atmospheric transfer
   c. Cyclic - symbiotic relationship
2. 20 lbs. VS/1000 ft^2/day
3. Lagoon depth 11.5 - 15 ft.

C. Anaerobic Liquid Sludge Lagoons
1. Lagoon depth 15 - 35 ft.
2. 5 ft. water cap
3. No surface agitation
4. MSDGC

IV. OTHER OPERATIONAL CONCERNS

A. Monitoring
1. Sensory observations
2. Sludge loading
3. Quality and characteristics
4. Depth, date, time
5. Weather
6. Supernatant quality

B. Emergency Operating Procedures

1. Undigested sludge

C. Design shortcomings

1. Adverse weather
2. Small lagoon area

D. Troubleshooting

1. Odors
2. Insects
3. Strong supernatant

E. Maintenance

1. Remove weeds
2. Remove supernatant
3. Repair dikes

F. Safety

1. Gases
2. Hygiene

8

SLUDGE LAGOONS

NARRATIVE

Slide #

1. This module discusses the theory, the types, and recommended operating procedures for sludge lagoons.

2. The module was written by Ronald M. Sharman. Instructional design was done by Priscilla Hardin. Paul H. Klopping was Project Director.

3. Treatment of wastewater sludge by lagooning is a viable method of sludge dewatering when sufficient, economical land is available.

4. Digested sludge lagoons were originally considered temporary sludge storage devices. Prolonged storage proved to be an effective dewatering process.

5. Sludge lagoons are similar to sand drying beds in their modes of operation. Both operate with sludge being periodically drawn from a digester, placed in a lagoon (or sand bed), and removed after a period of drying.

6. In lagoons, sludge generally requires 1 to 3 years to achieve a predetermined solids concentration suitable for removal. The cycle is then repeated.

7. There are three basic types or variations of sludge lagoons. These are: 1) The sludge drying lagoon; 2) The facultative sludge lagoon; and 3) The anaerobic sludge lagoon.

8. These three variations of sludge lagoon systems contain common design, equipment, and operational requirements.

9. Sludge lagoons consist of some sort of retaining walls which are normally earthen dikes. These vary from two to four feet high for drying lagoons, and up to thirty-five feet high for anaerobic sludge lagoons at the Metropolitan Sanitary District of Greater Chicago.

10. The earthen dikes normally enclose a rectangular basin with a permeable bottom surface. Dikes should be of a shape and size to permit maintenance, mowing, and a roadway for equipment. Lagoon width and depth are controlled by the limitations of the sludge removal equipment.

11. Equipment common to all lagoons include: 1) sludge feed lines and metering pumps, 2) supernatant decant lines, and 3) some type of mechanical sludge removal equipment. In areas where permeable soils are unavailable, underdrains and associated piping may be required.

12. Operating procedures common to all lagoon systems involve: 1) Pumping the liquid sludge and filling the lagoon to a desired depth over a period of months. The pumped sludge is normally stabilized prior to application.

13. 2) Depending on the climate and the depth of applied sludge, the time involved for dewatering may vary. (This may range from 1 to 3 years.)

14. 3) Decanting supernatant, either continuously or intermittently, from the lagoon surface and returning it to the headworks of the wastewater treatment plant.

15. 4) Removing the dewatered sludge with some type of mechanical removal equipment with ultimate disposal as land application or landfill.

16. 5) Resting (adding no new sludge) the lagoon for three to six months and 6) Repeating this cycle.

17. Proper design of the sludge lagoon systems requires close attention to the following considerations: 1) Climate, 2) Subsoil permeability, 3) Sludge characteristics, 4) Lagoon depth.

18. Proper size of the lagoon requires climatic information concerning: 1) Precipitation rate, 2) Evaporation rate, 3) Temperature extremes. The role of evaporation in dewatering is especially important in the process of drying lagoons.

19. The bottom of the lagoon should be a minimum of 18 inches above the ground water table. The subsoil should have a moderate permeability, highly permeable soils may require synthetic liners.

20. The characteristics of the sludge placed in a lagoon significantly affect odor and vector problems that can be produced. It is recommended that only anaerobically digested sludge be used for lagoon applications. Aerobically digested sludges have been used with some success.

21. Stable liquid sludges with less than 10% solids can be stored in most lagoons. Air dried, stable sludges of greater than 30% solids can be stored safely without odors.

22. Lagoon storage is not suitable for unstabilized, dewatered or partially dried sludge (less than 30% solids) because of the problems associated with septicity. (Odors and poor solids transport properties.)

23. The actual depth and area requirements for sludge lagoons varies depending on climatic conditions, sludge type, and lagoon volume. Wet climates may require greater sludge stability and lagoon area to attain good dewaterability. Drier climates may be able to handle a greater sludge volume in a smaller lagoon area.

24. A minimum of two separate lagoons are provided to ensure availability of storage space during cleaning, maintenance, and emergency conditions.

25. Recall that lagoons are used for dewatering, some further decomposition, and storage of wastewater sludges. Let's take a closer look at the three different types of sludge lagoons.

26. Sludge drying lagoons are low cost, simple systems which closely resemble sludge drying beds because the applied sludge is left exposed for actual drying to take place. Drying beds can be converted into drying lagoons by extending the sidewall depth with planking.

27. Drying lagoons have a sidewall dike height of 2 to 4 feet. Sludge is applied to a depth between 2 - 3.5 feet. After decanting, the drying depth averages about 15 inches.

28. Applied sludge depth can be greater in warmer climates where the annual rainfall is low and longer drying periods are possible.

29. Solids loading rates suggested for sludge drying lagoons range between 2.2 - 2.4 lbs/yr/ft^3 of lagoon capacity. After about one year of drying time, the sludge is dewatered from 5% solids to about 40% solids.

30. At the end of the drying cycle sludge drying lagoons are cleaned by using a front-end loader or other equipment which can enter the lagoon to remove the dried sludge. The dewatered sludge can then be hauled away to a final disposal site.

31. Facultative sludge lagoons differ from sludge drying lagoons in that the sludge is never left exposed for actual drying to take place. These lagoons are designed to maintain an aerobic surface layer free of scum or membrane-film buildup.

32. The aerobic layer is maintained by keeping the annual organic loading rate to the lagoon at or below 20 pounds of volatile solids per 1,000 square feet of surface area per day and by insuring efficient O_2 transfer at the lagoon surface.

33. Oxygen transfer takes place naturally with the growth of photosynthetic algae in the lagoon surface layer. Surface mixers provide agitation and mixing of the upper layer to support aerobic conditions.

34. Brush-type floating surface mixers have been the most successful used to provide agitation. Mixers are most effective when located downwind where the most scum accumulates. Mixers operate 6 to 12 hours a day to maintain scum-free conditions.

35. As the sludge is added to this lagoon, the digested sludge solids settle to the bottom of the basin. Sludge liquor or supernatant is periodically returned to the plant headworks to maintain a constant liquid level.

36. Facultative sludge lagoons must operate in conjunction with anaerobic digesters. They cannot function properly when supplied with either unstabilized or aerobically digested sludge because of possible odor problems.

37. The practical depth of a facultative lagoon is controlled by the limitation of commercially available dredges with the proven capacity of removing solids from beneath liquid surfaces. Such equipment is capable of removing sludge up to 15 feet deep.

38. Under normal operating conditions, sludge is applied to the lagoon for a year, allowed to dry or concentrate for 18 months, cleaned, and then the supporting material is "rested" for six months.

39. Anaerobic sludge lagoons are designed for solids decomposition under anaerobic conditions. Depths of an anaerobic lagoon can vary between 15 and 35 feet. A 5 foot water cap is used to contain odors. No surface agitation is used in this application.

40. Limited data is available for ASL however, operational data from the Metropolitan Sanitary District of Greater Chicago showed a solids loading rate of between 36 - 50 lbs volatile solids per 1000 ft^2 per day. Chicago reports anaerobic lagoon system accomplishes an overall volatile solids reduction of 17%.

41. Monitoring of sludge lagoons generally consists of sensory observations and interpretations by the plant operator. Records are kept on sludge loading, sludge quality, weather conditions, and supernatant volume.

42. Monitoring results provides the operator with the information necessary to determine the optimal time of sludge removal from the lagoon. Keeping a close eye on the supernatant quality helps the operator foresee any problems the supernatant may cause as it is pumped back to the plant.

43. In addition to the normal filling and cleaning procedures, other operational concerns include 1) Physical maintenance, 2) Water level management, 3) Nuisance control.

44. Maintenance requirements are very low for sludge lagoons. Follow manufacturers' recommendations for care of all mechanical equipment such as aerators, pumping and dredging machinery. Give regular attention to dike errosion, replacement of rip-rap, and roadway condition.

45. Water level management practices vary for different lagoon systems. In drying lagoons the operator should promptly remove supernatant liquor and rainwater to expose the cake to the air. In facultative or anaerobic systems, a constant level is maintained and excess supernatant is removed as it accumulates.

46. Nuisance control is another important operational concern. Remove weeds and other vegetation from the lagoon area and dikes before filling with sludge. Control offensive odors by chemical masking agents or by adding chloride of lime to the sludge as it is discharged to the lagoon. Flies may be a problem in some areas and are controlled by elimation of breeding environments and by the use of traps and poisons.

47. The only emergency that may directly affect the operation of the sludge lagoon is anaerobic digestor upset. Undigested or poorly digested sludge applied to lagoons is likely to result in odor problems.

48. Don't overlook safety considerations unique to lagoon operations. Since anaerobic digestion of sewage sludge produces combustible gases, smoking or open flames should be prohibited when discharging digested sludge to the lagoon. Fencing and warning signs may be desirable to prevent trespassing. Washing facilities should be available for both machinery and personnel. Provide life jackets and emergency floatation gear around dredging and maintenance equipment.

49. Sludge lagooning, whether it be drying, facultative, or anaerobic, is a good mechanism for dewatering sludge. Some volatile solids reduction is also achieved, especially in facultative or anaerobic systems.

50. Dewatering by lagooning is a very cost effective method when land is easily available. Lagoon operation is only one component of the wastewater solids treatment process and must be integrated into the overall wastewater treatment system.

WORKSHEET

Multiple Choice - Place an "X" by the best answer(s) or select answers as directed in the question.

1. Sludge lagoons are another method of:

   ____ a. Sludge conditioning

   __X__ b. Sludge dewatering

   ____ c. Sludge incineration

   ____ d. Sludge chemical treatment

2. Lagoons (are/are not) typically provided with an underdrain system.

   ____ a. Are

   __X__ b. Are not

3. Before sludge is added to a lagoon system, it should be:

   __X__ a. Stabilized

   ____ b. Unstabilized

   ____ c. Heated

   ____ d. Tasted

4. Some of the equipment commonly associated with sludge lagoons includes:

   ____ a. Heat exchangers

   ____ b. Scum baffles

   __X__ c. Supernatant decant lines

   __X__ d. Sludge removal equipment

5. Place the following in sequential order of operation.

   __C__ Decant supernatant.

   __D__ Remove dewatered sludge.

   __F__ Repeat cycle.

   __A__ Pumping liquid feed sludge.

   __E__ Allow resting period.

   __B__ Fill to desired depth.

6. The property of soil which allows fluid to pass, with the possibility of ground water contamination, is called:

   ____ a. Porosity

   ____ b. Passability

   ____ c. Stability

   __X__ d. Permeability

7. Sludge drying lagoons have suggested loading rates of:

_____ a. 1.0 - 1.9 lb./yr./ft.^{3}

__X__ b. 2.2 - 2.4 lb./yr./ft.^{3}

_____ c. 2.4 - 2.7 lb./yr./ft.^{3}

_____ d. 3.0 - 5.0 lb./yr./ft.^{3}

8. Drying lagoons resemble sludge drying beds more closely than facultative or anaerobic lagoons because:

_____ a. They have the same dimensions.

__X__ b. Sludge is exposed to air.

_____ c. Loading rates are the same.

_____ d. Sludge depth is the same.

9. Facultative lagoons are designed to maintain a surface layer that is:

__X__ a. Aerobic

_____ b. Anaerobic

_____ c. Absorptive

_____ d. Alkaline

10. Along with the oxygen supplying reaction of the cyclic - symbiotic relationship between bacteria and algae, two other mechanisms are utilized for oxygen transfer. The two are:

__X__ a. Atmospheric transfer

_____ b. Anabolism

_____ c. Turbine sparging

__X__ d. Mechanical aeration

11. Facultative sludge lagoons cannot function when supplied with sludge that is:

_____ a. Chemically treated

__X__ b. Aerobically digested

__X__ c. Unstabilized

_____ d. Anaerobically digested

12. Common depths of an anaerobic lagoon can vary between:

_____ a. 5 - 12 feet.

__X__ b. 15 - 35 feet.

_____ c. 40 - 50 feet.

_____ d. 400 - 1000 feet.

13. Anaerobic sludge lagoons are designed to operate with:

X a. A 5-foot water cap.

___ b. Two brush aerators.

___ c. 57 volatile solids reduction.

___ d. Chorella type algae

14. Monitoring of sludge lagoons generally consists of:

___ a. Heavy metals analysis

___ b. Color measurements.

X c. Sensory observation.

___ d. TOC calculations.

15. Sludge lagoon operational emergencies generally consist of:

___ a. Dike erosion.

___ b. Increasing supernatant concentration.

___ c. Low solids content.

X d. Loss of sludge digestion process.

16. Some suggested methods for controlling offensive odors include the use of:

X a. Chemical masking agents.

X b. Fencing off lagoon area.

___ c. Increasing solids loading.

___ d. Chloride of lime added to the sludge feed line.

17. What effect can the lagoon process have on the overall wastewater treatment scheme?

___ a. Increase costs.

___ b. Create dangerous operation.

___ c. Increase pH.

X d. Poor supernatant can increase loading.

18. Major safety considerations take into account primarily:

X a. Personal hygiene.

___ b. Solids concentration.

___ c. Access road speed.

___ d. Chorella.

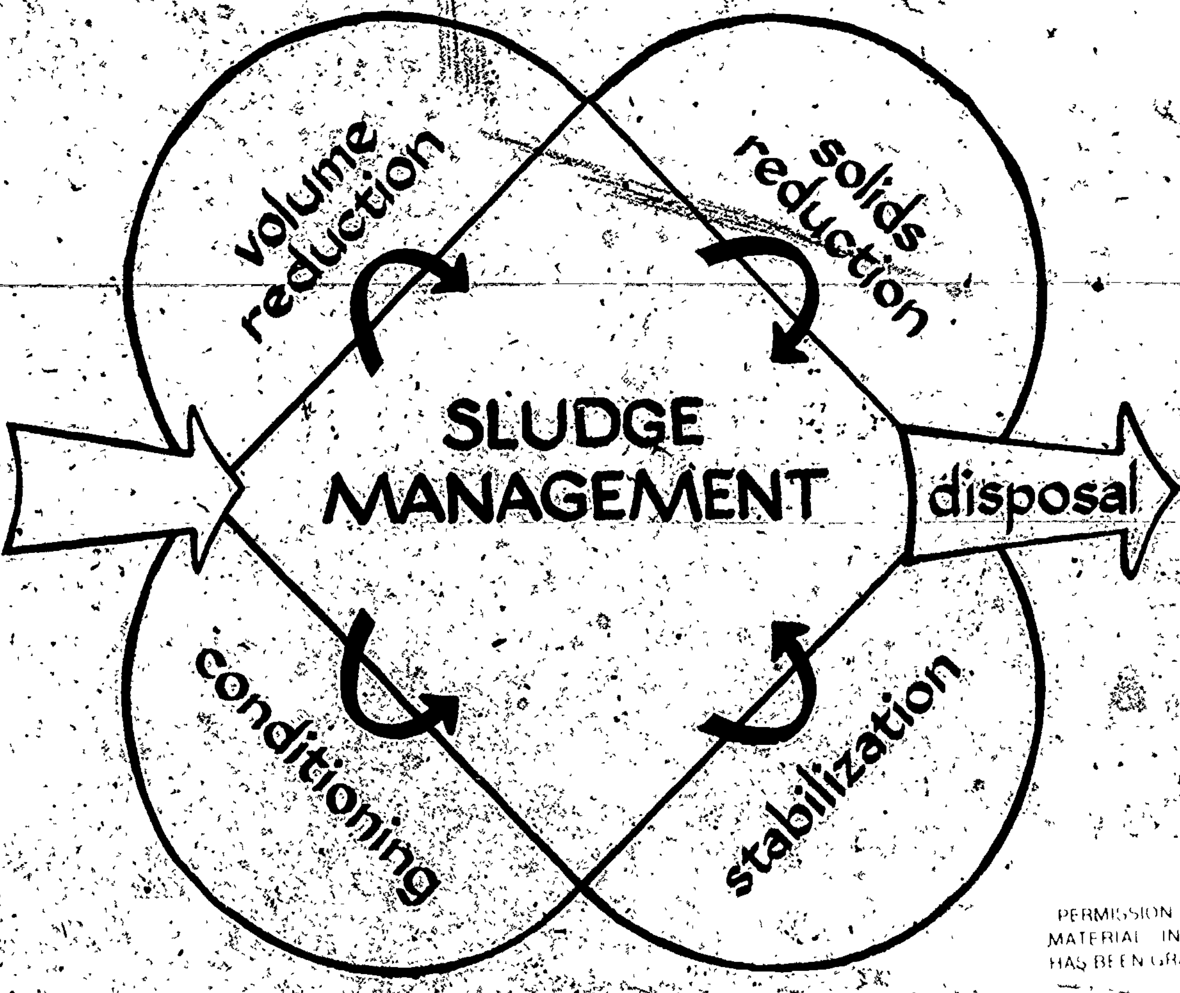
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

SLUDGE LAGOONS



STUDENT WORKBOOK

Prepared by
Linn-Benton Community College
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SLUDGE LAGOONS

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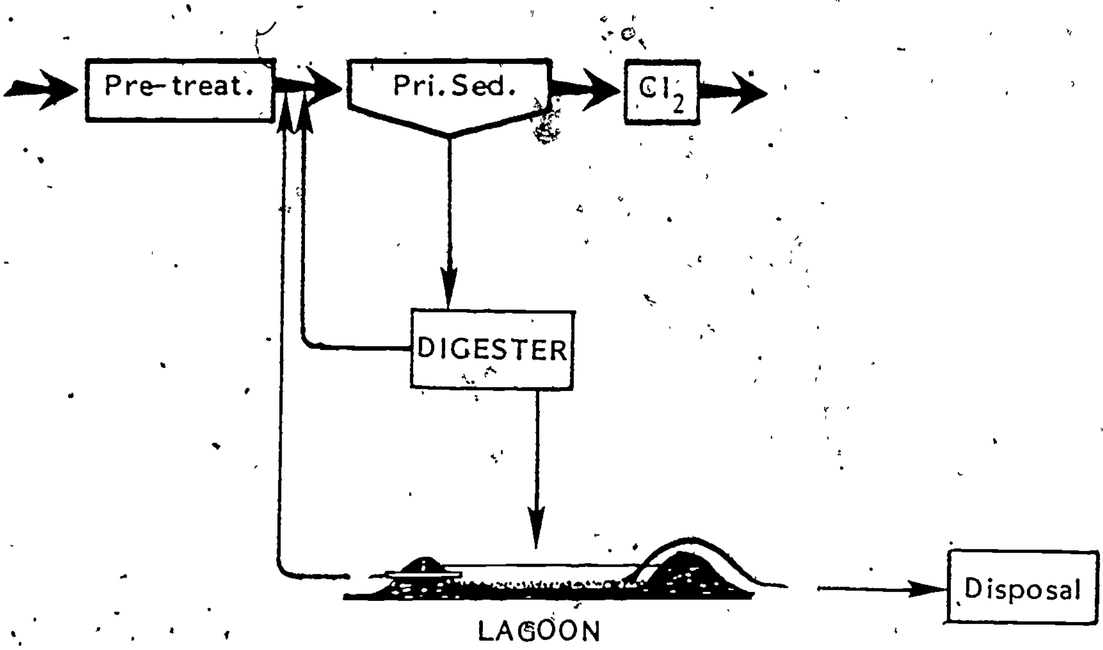
SLUDGE LAGOONS

CONTENTS

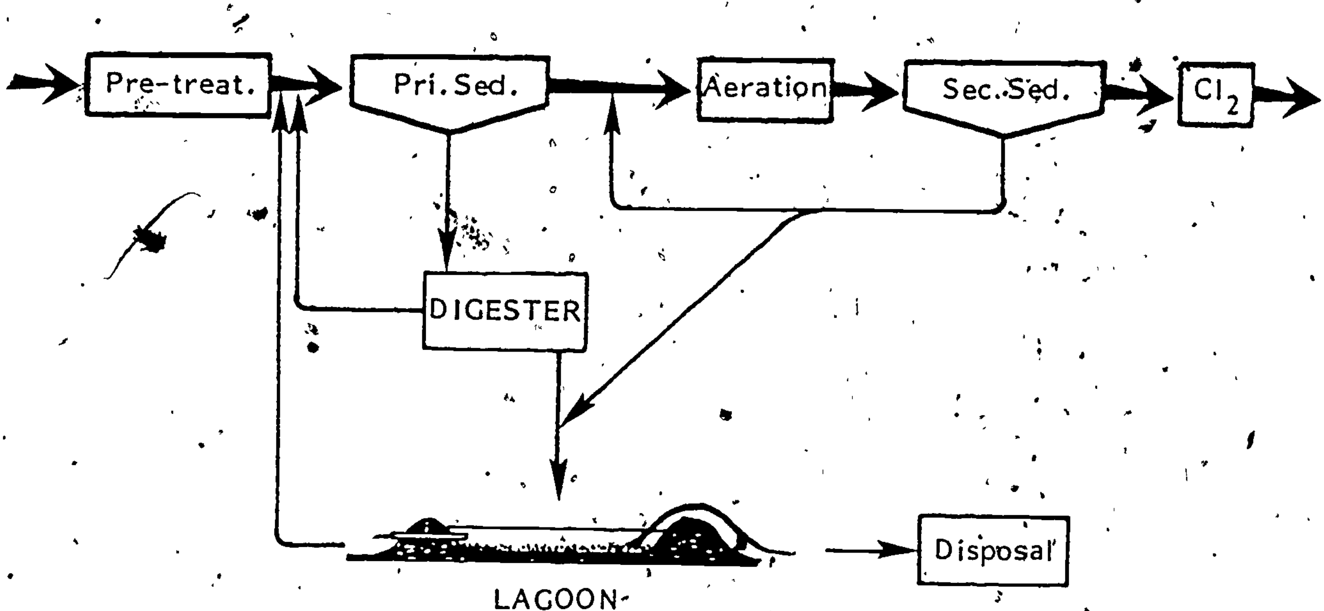
21

PLANT FLOW DIAGRAMS

PRIMARY PLANT



SECONDARY PLANT



SLUDGE LAGOONS

OBJECTIVES

Upon completion of this lesson you should be able to do the following:

1. Explain how lagoon, as a treatment process, fits into the overall wastewater treatment scheme.
2. Explain why a sludge drying lagoon resembles sludge drying beds.
3. Describe the equipment which is common to all sludge lagoon variations.
4. List the six operating procedures common to all types of lagoon systems.
5. Explain how the following design criteria affect sludge lagoon operation:
   a) Climate
   b) Subsoil permability
   c) Sludge characteristics
   d) Depth and area
6. Recall that lagoon storage is not suitable for unstabilized, dewatered, or partially dired sludge because of the problems with septicity.
7. Describe sludge drying lagoons.
8. Recall the sludge loading rate if the sludge drying lagoon is 2.2 - 2.4 $lbs/yr/ft^3$ of lagoon capacity.
9. Describe facultative sludge lagoons.
10. Recall that the sludge loading rate of the facultative lagoon is 20 lbs VS/1,000 ft^2/day.
11. Describe anaerobic sludge lagoons.
12. Explain the mechanisms of O_2 supply in a facultative lagoon.
13. Explain why receiving undigested feed sludge is the major emergency encountered during lagoon operation.
14. Recall that lagoons are used for dewatering, further decomposition, and storage of wastewater sludges.
15. Describe the general maintenance considerations of sludge lagoon systems.
16. Describe the causes of odor problems and what can be done to solve them.
17. Explain the effects of poor supernatant quality on the treatment plant and what can be done to improve on supernatant quality.

SLUDGE LAGOONS

GLOSSARY

Aerobic - A condition in which "free" or dissolved oxygen is present in the aquatic environment.

Anaerobic - A condition in which "free" or dissolved oxygen is not present in the aquatic environment.

Decant - To pour off without disturbing the sediment.

Dewater - To drain or remove water from sludge.

Facultative - Pond: The opper portion (supernatant) is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.

Permeability - (1) The property of a material that permits appreciable movement of water through it when it is saturated and the movement is actuated by hydrostatic pressure of the magnitude normally encountered in the natural subsurface water. (2) The capacity of a rock or rock material to transmit a fluid.

Septicity - The condition in which organic matter decomposes to form foul smelling products associated with the absence of free oxygen.

Solids Concentration - The amount or percentage of solids in a unit volume of water.

Stabilized Sludge - A sludge that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the sludge would not cause odors.

Supernatant - Floating on surface, like oil on water. The liquid overlying deposited solids.

Symbiotic - The living together or close association of two dissimilar organisms with mutual benefit.

Volatile Solids - The quantity of solids in water, sewage or sludge, lost on ignition of the dry solids at 600° C.

INTRODUCTION

*dewatering method
*similiar to sand drying beds

Sludge lagoons are another method of sludge dewatering when sufficient, economical land is available. Sludge lagoons are similar to sand drying beds in their modes of operation. Both operate with sludge being periodically drawn from a digester, placed in a lagoon (or sand bed), removed after a period of drying, and the cycle is repeated. Lagoons, however, are not typically provided with an underdrain system because most of the drying is accomplished by decanting supernatant liquor and by evaporation. Also, sludge is placed at depths three to four times greater than it would be in a drying bed. And, in fact, some sludge drying beds are temporarily converted to drying lagoons by increasing the sludge depth.

1 - 3 years storage
*stabilized sludge only

Generally, sludge is allowed to dewater and dry to some predetermined solids concentration before removal and this may require one to three years. The cycle is then repeated. Sludge should be stabilized prior to addition to the lagoon to minimize odor problems.

BASIC CONCEPTS

Different operational variations of the treatment process of sludge lagooning contain common design and equipment requirements. Sludge lagoons consist of some sort of retaining wall which are normally earthen dikes. These vary from two to four feet high for drying lagoons to 35 feet high for anaerobic lagoons at the Metropolitan

Dikes
*allow for maintenance

Equipment
*sludge feed
*meters
*decant lines
*removal equipment

Sanitary District of Greater Chicago (MSDGC) Prairie Plan land reclamation project in Fulton County, Illinois. The earthen dikes normally enclose a rectangular space with a permeable surface. Dikes should be of a shape and size to permit maintenance, mowing, and entrance of trucks and front-end loaders to the lagoons for sludge removal.

Appurtenant equipment includes: sludge feed lines and metering pumps, supernatant decant lines, and some type of mechanical sludge removal equipment. The removal equipment can include a bulldozer, drag line or front-end loader. In areas where permeable soils are unavailable, underdrains and associated piping may be required

Operating procedures common to all types of lagoon systems involve:

1 - Pumping liquid sludge, over a period of several months or more, into the lagoon. The pumped sludge is normally stabilized prior to application.
2 - Filling the lagoon to a desired sludge depth and then permitting it to dewater. Depending on the climate and the depth of applied sludge, the time involved for dewatering to a final solids content of between 20 to 40 percent solids may be 3 to 12 months.
3 - Decanting supernatant, either continuously or intermittently, from the lagoon surface and returning it to the headworks of the wastewater treatment plant.
4 - Removing the dewatered sludge with some type of mechanical removal equipment.

5 - Resting (adding no new sludge) to the lagoon for three to six months.

6 - Repeating the cycle.

Design Criteria

Proper design of sludge lagoons requires a consideration of the following factors: climate, subsoil permeability, sludge characteristics, lagoon depth, and area management practices.

Climate

Precipitation
Evaporation
Temperature Ranges

After dewatering by drainage and supernating, drying in a sludge lagoon depends primarily on evaporation. Proper size of a lagoon, therefore, requires climatic information concerning:

1 - Precipitation rate (annual and seasonal).

2 - Evaporation rate (annual average, range, and seasonal fluctuations).

3 - Temperature extremes.

Subsoil Permeability

Soil?

The subsoil should have a moderate permeability of 1.6×10^{-4} to 5.5×10^{-4} inches per second, and the bottom of the lagoon should be a minimum of 18 inches above the maximum ground water table, unless otherwise directed by local authorities

Sludge Characteristics

Sludge Characteristics?

The type of sludge to be placed in a lagoon can significantly affect the amount and type of odor and vector problems that can be produced. It is recommended that only those sludges which have been anaerobically digested be used for lagoon applications. Stable liquid sludge with less than 10% solids can be stored in most lagoons. When it is air dried to greater than 30 to 40% solids, stable sludge can be stored safely and without odors. It is impractical to store unstabilized, dewatered or partially dried sludge (less than 30% solids) because problems associated with septicity (odors, poor solids transport properties) can develop.

Odor Potential!

Nuisance odors will not develop in anaerobic storage when sufficient methane bacteria are present. If the methane bacteria are destroyed, however, serious odor problems may result. As an example, consider anaerobically digested sludge which is placed on a drying bed or in a drying lagoon. The top layer of sludge is dewatered, and methane bacteria die as the sludge aerates and dries. Odor levels are extremely low, since the sludge is too dry to support anaerobic biological activity. Should the surface of the sludge be rewetted (for example, by rainfall or surface flooding), however, anaerobic activity would resume, the organic acid concentration would rapidly increase, and odors would increase to nuisance levels. Odor problems experienced with approximately 580 acres of drying lagoons at San Jose, California, immediately following a rainstorm, is an example of this type of problem.

Lagoon Depth and Area

The actual depth and area requirements

for sludge lagoons depends on several factors such as precipitation, evaporation, type of sludge, volume and solids concentration. Solids loading criteria have been given as 2.2 to 2.4 pounds of solids per year per cubic foot capacity for drying lagoons to 20 pounds of volatile solids per 1,000 square feet surface area for facultative lagoons. A minimum of two separate lagoons are provided to ensure availability of storage space during cleaning, maintenance, or emergency conditions.

General Guidance

Lagoons may be of any shape, but a rectangular shape facilitates rapid sludge removal. Lagoon dikes should have a slope of 1:3, vertical to horizontal, and should be of a shape and size to facilitate maintenance, mowing, passing of maintenance vehicles atop the dike, and access for entry of trucks and front-end loaders into the lagoon. Surrounding areas should be graded to prevent surface water from entering the lagoon. Return must exist for removing the surface liquid and piping to the treatment plant. Provisions must also be made for limiting public access to the sludge lagoons.

Keep surface water out

Limit public access

LAGOON TYPES

Lagoons - 3 Types
*Sludge Drying
*Facultative
*Anaerobic

Lagoons used for dewatering, some decomposition, and storage of wastewater sludges are classified into three areas:

Sludge Drying Lagoons
Facultative Sludge Lagoons
Anaerobic Sludge Lagoons

Sludge Drying Lagoons

Lagoon drying is a low-cost, simple system for sludge dewatering that is commonly used in the United States. Drying lagoons resemble sludge drying beds more closely than the other two lagoon systems because the applied sludge is left exposed for actual drying to take place.

Solids loading rates suggested for drying lagoons are 2.2 to 2.4 lb /yr /cu ft of lagoon capacity. Other designers have made recommendations ranging from 1 sq. ft./capita for primary digested sludges in an arid climate to as high as 3 to 4 sq. ft./capita for activated sludge plants where the annual rainfall is 36 inches. A dike height of about 2 feet with the depth of applied sludge between 24 to 48 inches and the depth of sludge after decanting of 15 inches has been used. Sludge depths of 2.5 to 4 feet may be used in warmer climates where longer drying periods are possible. Sludge may be dewatered from 5% solids to 40 to 45% solids in 2 to 3 years, using sludge depths of 2 to 4 feet.

Drying Time
*2-3 years

ADVANTAGES AND DISADVANTAGES OF USING SLUDGE DRYING LAGOONS

Advantages	Disadvantages
Lagoons are low energy consumers Lagoons consume no chemicals Lagoons are not sensitive to sludge variability	Lagoons may be a source of periodic odor problems, and these odors may be difficult to control
The lagoons can serve as a buffer in the sludge handling flow stream. Shock loadings due to treatment plant upsets can be discharged to the lagoons with minimal impact	There is a potential for pollution of groundwater or nearby surface water
Organic matter is further stabilized Of all the dewatering systems available, lagoons require the least amount of operation attention and skill	Lagoons can create vector problems (for example, flies and mosquitos) Lagoons are more visible to the general public
If land is available, lagoons have a very low capital cost	Lagoons are more land-intensive than fully mechanical methods Rational engineering design data are lacking to allow sound engineering economic analysis

Aerobic Surface
*mixers help
*Algae

Facultative Sludge Lagoons

Facultative Sludge Lagoons (FSL's) are designed to maintain an aerobic surface layer free of scum or membrane-type film build-up. The aerobic layer is maintained by keeping the annual organic loading to the lagoon at or below a critical area loading rate of 20 pounds of volatile solids per 1,000 square feet per day and by using surface mixers to provide agitation and mixing of the aerobic surface layer. For example, FSL's with surface areas of from 4 to 7 acres require the operation of two surface mixers from 6 to 12 hours per day to successfully maintain scum-free surface conditions. All of the successful installations, to date, have used brush-type floating surface mixers to achieve the necessary surface agitation. The aerobic surface layer of the FSL's is usually from one to three feet in depth and supports a very dense population of between 50×10^3 and 6×10^6 organisms/ml of algae (Chorella) Dissolved oxygen is supplied to this layer by algal photosynthesis, by direct surface transfer from the atmosphere, and by the surface mixers. The oxygen is used by the bacteria in the aerobic degradation of colloidal and soluble organic matter in the digested sludge liquor, while the digested sludge solids settle to the bottom of the basins and continue their anaerobic decomposition. Sludge liquor or supernatant, is periodically returned to the plant's liquid process stream.

Algae
*symbiotic relationship
*prevents odors

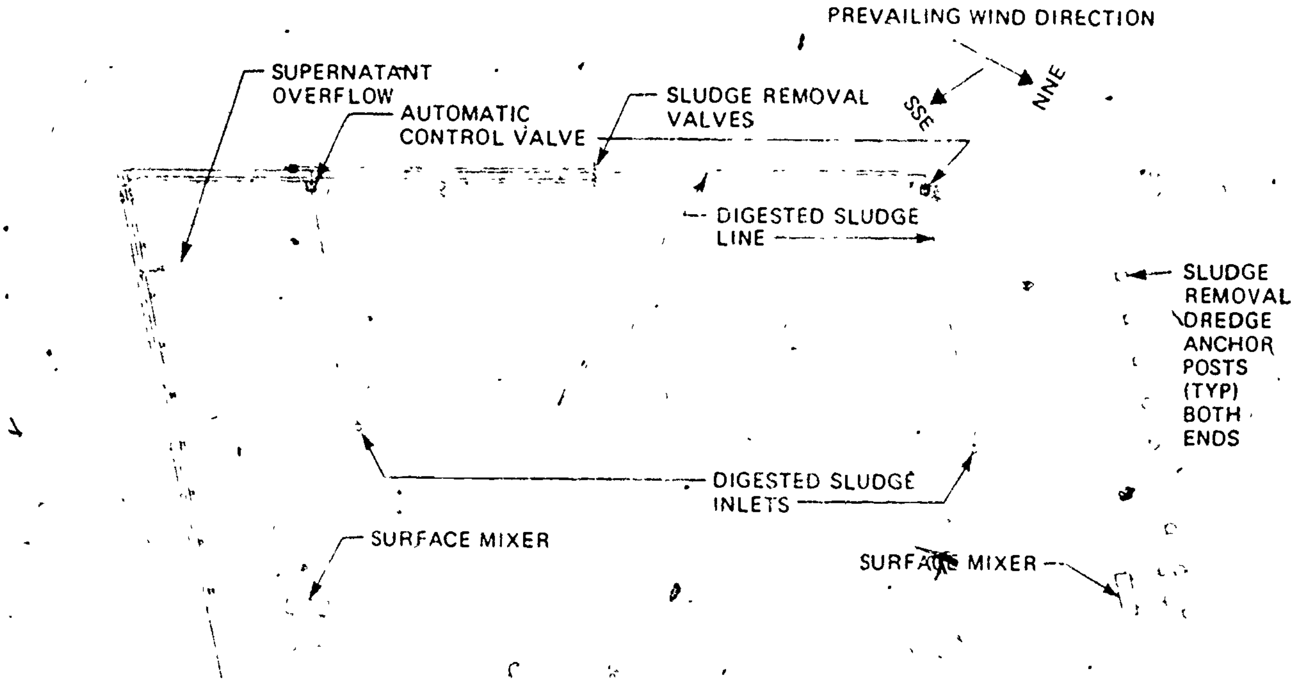
The nutrient and carbon dioxide released in both the aerobic and anaerobic degradation of the remaining organic matter within the digested sludge are, in turn, used by the algae in the cyclic-symbiotic relationship. This vigorous relationship maintains the pH of the FSL surface layer between 7.5 and 8.5, which effectively minimizes any hydrogen sulfide (H_2S) release and is believed to be one of the major keys to the successful operation of this sludge storage process.

Facultative Sludge Lagoons
*require anaerobic digesters

*dredge for solids removal

Facultative sludge lagoons must operate in conjunction with anaerobic digesters. They cannot function properly when supplied with either unstabilized or aerobically digested sludge. If the acid phase of anaerobic stabilization becomes predominant, the lagoons will produce odors.

FSL depth was established by the practical limitation of commercially available dredges with a proven capability of removing waste water solids from beneath liquid surfaces Equipment that meets this requirement is available to extract sludge from FSLs up to 11.5 and 15 feet



TYPICAL FSL LAYOUT

Water Cap
*prevents odors

Anaerobic Liquid Sludge Lagoons

Anaerobic sludge lagoons are designed for decomposition under anaerobic conditions Depths of an anaerobic lagoon can vary between 15 to 35 feet Anaerobic decomposition takes place in varying sludge layers utilizing at least a 5-foot water cap to contain odors. No surface agitation is used in this application.

Operational data from the Metropolitan Sanitary District of Greater Chicago's Prairie Plan Land Reclamation Project indicates a feed sludge of 57% volatile solids which is loaded to different lagoons at rates of 36 to 50 pounds volatile solids per 1000 sq. ft. per day These anaerobic lagoon systems accomplish an overall volatile solids reduction of 17 percent.

In this operation the lagoon supernatant is disposed of on 1,320 acres of alfalfa-brome hay fields. Average annual quantity to dispose equals 700,000 wet tons with an average ammonia content of 109.9 mg/l and an average TKN content of 156.4 mg/l.

OTHER OPERATIONAL CONCERNS

Monitoring
*loading
*sludge quality
*characteristics
*depth
*date
*time
*weather
*supernatant

Monitoring

Monitoring of sludge lagoons generally consists of sensory observations and interpretations by the plant operator. However, records may be kept on the sludge loading, sludge quality and characteristics, depth, date, time, weather conditions, supernatant volume and quality. This will provide the operator with the information necessary to determine the optimal time of sludge removal from the lagoon. Keeping a close eye on the supernatant quality will help the operator foresee any problems the supernatant may cause as it is pumped back to the plant.

Emergency Operating Procedures

The only emergency that may directly affect the operation of the sludge lagoon is the loss of the sludge digestion process. Undigested or poorly digested sludge applied to lagoons is likely to result in an odor problem and should be avoided.

Design Shortcomings

Adverse weather conditions may prolong the drying of sludge, however, short rainy periods followed by sunny conditions should pose no problems. Problems of too little lagoon area may be minimized by always removing the sludge when it is dry enough and removing supernatant as it forms

Low Maintenance

Maintenance Considerations

Maintenance requirements are very low for sludge lagoons. Weeds and other vegetation should always be removed from the lagoon area before filling with sludge. The operator should promptly remove supernatant liquor and rain water so that the sludge cake is exposed to oxygen in the air and can dry rapidly in drying lagoons. In facultative or anaerobic systems, a constant level is maintained and excess supernatant is removed as it accumulates.

Repairing of broken dikes and water from rainfall or snow require minimal operator time.

Odor Control
*Masking agents
*Lime

Troubleshooting

Odor Problems

Two basic approaches are available to control or counteract odors: chemicals sprayed into the atmosphere or chemicals added to the sludge. Chemicals are available which may be sprayed into the atmosphere in the vicinity of the odor to counteract or mask the odors. Odors may also be controlled effectively by adding chloride of lime to the sludge as it is discharged to sludge drying lagoons.

Odors can also be caused by a loss or decrease in aeration potential of facultative lagoons or by a too shallow water cap in anaerobic systems.

Fly Control
*traps and poison
*borax
*calcium borate
*chloride of lime
*sulfate of iron

Flies may be a problem in certain areas and seasons and should be controlled by destruction of breeding and use of traps and poisons. The fly may be controlled most effectively in the larva stage and borax or calcium borate will kill the larva. Neither chemical is dangerous to man nor domestic animals. Other chemicals sometimes used are chloride of lime and sulfate of iron. The adult fly can be killed by spraying.

In considering the sludge lagoon as part of the overall process of wastewater treatment, we can see the possible effects the lagoon may have on the rest of the system. Supernatant decanted from the lagoon can upset the treatment process when it is recycled. Some causes of degraded supernatant include:

1 - Broken dikes between lagoons allowing for fresh feed sludge to mix with supernatant.
2 - Supernatant being drawn down prematurely.
3 - Excessive sludge depths applied causing supernatant draw off to be below the sludge interface.

Poor Supernatant
*Broken dikes
*Early drawdown
*Excessive sludge depth

Problems of degraded supernatant quality can be solved by a good strategy of operation and a program of supernatant monitoring.

Safety
*No Smoking
*Fencing
*Hygiene Facilities

Safety Considerations

Since anaerobic digestion of sewage sludge produces combustible gases, smoking or open fires should be prohibited when discharging anaerobically digested sludge to the lagoon. Fencing of lagoons may be desirable to prevent trespassing. Washing facilities should be available for both machinery and personnel. Personal hygiene must be of concern because of the nature of the material being treated.

Costs

Cost information on capital cost of construction of sludge lagoons is almost nonexistent.

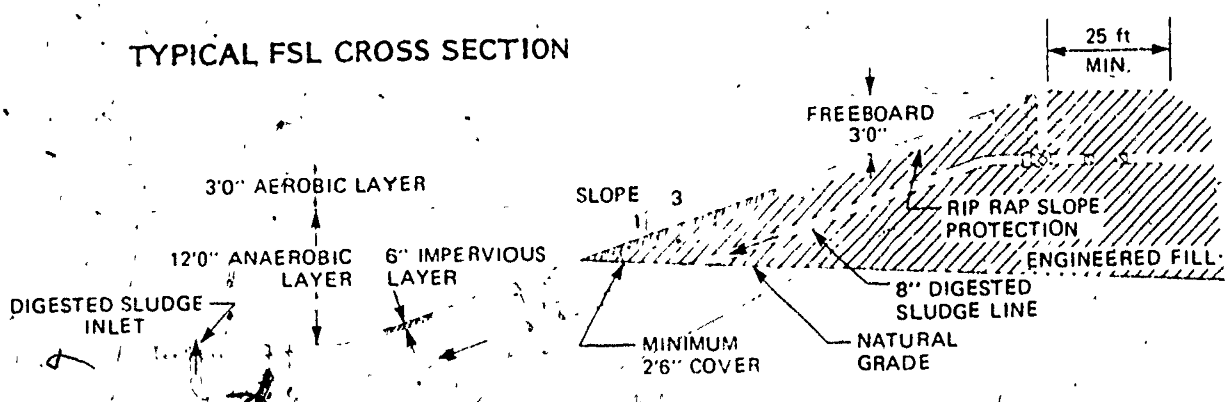
Labor requirements for sludge dry lagoons are covered in the following table. The requirements include: application of sludge to the lagoon; periodic removal of supernatant; periodic removal of solids; and minor maintenance requirements.

The major elements involved in determining facultative sludge lagoon costs are land and earth moving, both are quite site specific. For example, a typical FSL storage facility for a 10 MGD secondary activated sludge treatment plant with primary sedimentation, anaerobic digestion, and normal strength domestic and industrial sewage will cost about $25,000 per year to operate (1978 dollars). Some of these operational costs being used to supply energy to the surface aerators. Addition of a dredge and/or booster pump would

ADVANTAGES AND LIMITATIONS OF USING FACULTATIVE SLUDGE LAGOONS FOR LONG-TERM STORAGE

Advantages	Limitations
Provides long-term storage with acceptable environmental impacts (odor and groundwater contamination risks are minimized).	1. Can only be used following anaerobic stabilization. If acid phase of digestion takes place in lagoons they will stink.
Continues anaerobic stabilization, with up to 45 percent VS reduction in first year.	2. Large acreages require special odor mitigation measures.
Decanting ability assures minimum solids recycle with supernatant (usually less than 500 mg/l) and maximum concentration for storage and efficient harvesting (>6 percent solids) starting with digested sludge of <2 percent solids.	3. Requires large areas of land, for example, 15 to 20 gross acres (6 to 8 ha) for 10 MGD, (438 l/s) 200 gross acres (80 ha) for 136 MGD (6,000 l) carbonaceous activated sludge plants.
Long-term liquid storage is one of few natural (no external energy input) means of reducing pathogen content of sludges.	4. Must be protected from flooding.
Energy and operational effort requirements are very minimum.	5. Supernatant will contain 300-600 mg/l of TKN, mostly ammonia.
Once established, buffering capacity is almost impossible to upset.	6. Magnesium ammonia phosphate (struvite) deposition requires special supernatant design.
Allows for all tributary digesters to operate as primary complete-mix units (one blending unit may be required for large installations).	
Provides environmentally acceptable place for disposal of digester contents during periodic cleaning operations.	
Sludge harvesting is completely independent from sludge production.	

TYPICAL FSL CROSS SECTION



1 ft = 0.3 m
1 in = 2.5 cm

NOT TO SCALE

add another $150,000 to $180,000 to the construction costs.

Lagoon
*Dewatering
*Cost Effective

Sludge lagooning, whether it be drying, facultative, or anaerobic, is a good mechanism for dewatering sludge. Dewatering is the removal of water from wastewater treatment plant solids to achieve a volume reduction. Some volatile solid reduction is also achieved, especially in facultative or anaerobic systems Dewatering by lagooning is a very cost effective method, when land is easily available It is done primarily to decrease the capital and operating costs of direct sludge disposal or conversion. Dewatering sludge from a 5 to a 20 percent solids concentration reduces volume by three-fourths and results in a non-fluid material. Dewatering is only one component of the wastewater solids treatment process and must be integrated into the overall wastewater treatment system so that performance of both the liquid and solids treatment schemes is optimized and total costs are minimized.

SLUDGE LAGOONS

References

1. Process Design Manual for Sludge Treatment and Disposal, USEPA, EPA 430/9-78-011, Cincinnati, 1979.

2. Operations Manual for Sludge Handling and Conditioning, USEPA, EPA 430/9-78-002, February, 1978.

3. WPCF Manual of Practice No. 20, Chapter 3, Sludge Dewatering.

4. Laboratory Study of Dewatering Rates for Digested Sludge in Lagoons, Jeffrey, E. A., Proceedings of 14th Purdue Industrial Waste Conference. Purdue University, Lafayette, Indiana 47907 1956

5. Dewatering Rates for Digested Sludge in Lagoons, Jeffrey, E. A., Journal Water Pollution Control Federation. Volume 32, p. 1153, 1960.

WORKSHEET

Multiple Choice - Place an "X" by the best answer(s) or select answers as directed in the question.

1. Sludge lagoons are another method of:
   _____ a. Sludge conditioning
   _____ b. Sludge dewatering
   _____ c. Sludge incineration
   _____ d. Sludge chemical treatment

2. Lagoons (are/are not) typically provided with an underdrain system.
   _____ a. Are
   _____ b. Are not

3. Before sludge is added to a lagoon system, it should be:
   _____ a. Stabilized
   _____ b. Unstabilized
   _____ c. Heated
   _____ d. Tasted

4. Some of the equipment commonly associated with sludge lagoons includes:
   _____ a. Heat exchangers
   _____ b. Scum baffles
   _____ c. Supernatant decant lines
   _____ d. Sludge removal equipment

5. Place the following in sequential order of operation.
   _____ Decant supernatant.
   _____ Remove dewatered sludge.
   _____ Repeat cycle.
   _____ Pumping liquid feed sludge.
   _____ Allow resting period.
   _____ Fill to desired depth.

6. The property of soil which allows fluid to pass, with the possibility of ground water contamination, is called:
   _____ a. Porosity
   _____ b. Passability
   _____ c. Stability
   _____ d. Permeability

7. Sludge drying lagoons have suggested loading rates of:

_____ a. 1.0 - 1.9 lb./yr./ft.^{3}

_____ b. 2.2 - 2.4 lb./yr./ft.^{3}

_____ c. 2.4 - 2.7 lb./yr./ft.^{3}

_____ d. 3.0 - 5.0 lb./yr./ft.^{3}

8. Drying lagoons resemble sludge drying beds more closely than facultative or anaerobic lagoons because:

_____ a. They have the same dimensions.

_____ b. Sludge is exposed to air.

_____ c. Loading rates are the same.

_____ d. Sludge depth is the same.

9. Facultative lagoons are designed to maintain a surface layer that is:

_____ a. Aerobic

_____ b. Anaerobic

_____ c. Absorptive

_____ d. Alkaline

10. Along with the oxygen supplying reaction of the cyclic - symbiotic relationship between bacteria and algae, two other mechanisms are utilized for oxygen transfer. The two are:

_____ a. Atmospheric transfer

_____ b. Anabolism

_____ c. Turbine sparging

_____ d. Mechanical aeration

11. Facultative sludge lagoons cannot function when supplied with sludge that is:

_____ a. Chemically treated

_____ b. Aerobically digested

_____ c. Unstabilized

_____ d. Anaerobically digested

12. Common depths of an anaerobic lagoon can vary between:

_____ a. 5 - 12 feet.

_____ b. 15 - 35 feet.

_____ c. 40 - 50 feet.

_____ d. 400 - 1000 feet.

13. Anaerobic sludge lagoons are designed to operate with:

_____ a. A 5-foot water cap.

_____ b. Two brush aerators.

_____ c. 57% volatile solids reduction.

_____ d. Chorella type algae

14. Monitoring of sludge lagoons generally consists of:

_____ a. Heavy metals analysis

_____ b. Color measurements.

_____ c. Sensory observation.

_____ d. TOC calculations.

15. Sludge lagoon operational emergencies generally consist of:

_____ a. Dike erosion.

_____ b. Increasing supernatant concentration.

_____ c. Low solids content.

_____ d. Loss of sludge digestion process.

16. Some suggested methods for controlling offensive odors include the use of:

_____ a. Chemical masking agents.

_____ b. Fencing off lagoon area.

_____ c. Increasing solids loading.

_____ d. Chloride of lime added to the sludge feed line.

17. What effect can the lagoon process have on the overall wastewater treatment scheme?

_____ a. Increase costs.

_____ b. Create dangerous operation.

_____ c. Increase pH.

_____ d. Poor supernatant can increase loading.

18. Major safety considerations take into account primarily:

_____ a. Personal hygiene.

_____ b. Solids concentration.

_____ c. Access road speed.

_____ d. Chorella.